Aerospatiale AS332L Super Puma, G-BWMG, 28 January 1998 at 1626 hrs

AAIB Bulletin No: 8/98 Ref: EW/C98/1/4 Category: 2.1

Aircraft Type and Registration:	Aerospatiale AS332L Super Puma, G-BWMG
No & Type of Engines:	2 Turbomeca Makila 1A turboshaft engines
Year of Manufacture:	1983
Date & Time (UTC):	28 January 1998 at 1626 hrs
Location:	About 40 nm east of Sumburgh
Type of Flight:	Public Transport
Persons on Board:	Crew - 2 - Passengers - 10
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Horizontal stabiliser detached
Commander's Licence:	Airline Transport Pilot's Lincence
Commander's Age:	49 years
Commander's Flying Experience:	13,820 hrs (of which 10,108 were on type)
	Last 90 days - 146 hours
	Last 28 days - 42 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft was returning to Aberdeen from the Tern Platform. It took off from the platform at 1553 hrs and, at 1604 hrs, was cleared direct to Aberdeen from Gate Juliet; the ETA was 1745 hrs. At 1626 hrs, while cruising at 130 kt and 2,500 feet amsl, the crew heard what they described as 'a loud bang'. The helicopter pitched rapidly nose down and yawed to the right; the crew thought that the nose down pitch was of the order of 30° but they could not recall the direction or amount of the yaw. The combined voice/flight data recorder (CVFDR) later indicated that the helicopter pitched 10° nose down and yawed 10° to the right. However the rapid rate of pitch-down was described as 'violent' by the crew and may have affected their appreciation of the amplitude of the sudden pitch-down; it is also possible that the sensing of the amplitude of this pitch down by the FDR attitude recording system may also have been adversely affected by the associated high rate. The autopilot then disengaged and the commander partially lowered the collective lever. There was a short period of pitch oscillation before the helicopter settled into a steady descent.

The co-pilot transmitted a MAYDAY call which was promptly acknowledged by the Sumburgh Radar controller. He then briefed the passengers for a possible ditching. The commander regained adequate control of the helicopter at about 1,600 feet amsl and increased power to climb initially to 2,000 feet amsl. The co-pilot informed ATC that they were having trouble with the yaw pedals and that they suspected that there was something wrong with the tail. The controller told him that the nearest land was Sumburgh and their bearing was 078° at 40 nm.

The crew discussed the problem and agreed that all flight deck indications were normal. Despite what they described as 'some roughness' there was no significant control problem and both engines appeared to be performing normally. The autopilot was re-engaged and the co-pilot reassured the passengers that the helicopter was back under control, but told them to keep their seat belts fastened and their immersion suits 'zipped up'. By 1629 hrs, the helicopter was again cruising at 2,500 feet but the commander decided to select a reduced power setting than that used before the incident and the indicated airspeed (IAS) stabilised at about 110 kt.

Meanwhile the Sumburgh Radar controller had arranged for an S61 helicopter which was in the area to act as escort and had vectored it towards 'MG'. The S61 crew made visual contact at 1631 hrs and it was agreed that it would approach on the right side and inspect that area of 'MG' before crossing to the left and coming into close formation. It was at this time that the commander reached the conclusion that the problem might be associated with the horizontal stabiliser. At 1635 hrs, the S61 crew asked him to reduce speed by 10 kt to enable them to formate sooner. This was agreed and the IAS was reduced to 100 kt. The commander felt that the helicopter and its occupants were no longer in immediate danger and the state of Emergency was downgraded to Urgency at 1638 hrs.

At 1641 hrs, the S61 crew confirmed that the horizontal stabiliser had detached cleanly and completely; there appeared to be neither loose debris nor significant other damage. The commander of 'MG' decided to discuss the problem with the commander of another company AS332 helicopter in the area. The commander of the latter confirmed that the stabiliser had no significant effect at low speed although he did point out that the loss of its mass from the rear would affect the centre of gravity. He suggested that it might be prudent to compensate for this by reseating the passengers as far to the rear as possible. This was done and, at 1645 hrs, the helicopter was cleared to land on Runway 27 at Sumburgh; the surface wind was 020°/6 kt. The crew decided that a 'run on' landing would be the safer option, the appropriate checks were done and the helicopter landed without further incident at 1649 hrs.

Meteorology

At about 1604 hrs, some 22 minutes before the incident, the co-pilot mentioned that they were experiencing some airframe icing, however they encountered no other significant weather and icing was not mentioned subsequently. The commander reported that the weather they were experiencing at the cruising altitude of 2,500 feet at the time of the incident was as follows:

Wind 355°/20 kt

Visibility Good

Cloud 4 octas base 3,000 feet

Temperature + 2°C

The crew listened to the Sumburgh Automatic Terminal Information System (ATIS) information 'Sierra' which was timed at 1627 hrs:

Surface Wind 020°/5 kt

Visibility 40 Km

Weather Nil

Cloud Scattered at 3,000 feet

Temperature + 2°C

Dewpoint -1°C

QNH 1020 mb

Human factors

Both crew members were qualified AS332 commanders. The commander had been operating in the North Sea since 1978 and had flown the AS332 since 1982. The co-pilot was also 49 years old and had been operating in the North Sea since 1980. He had flown the AS332 since 1987 and had a total of 10,054 hours, of which 3,950 were on type. The crew handled the incident as a team, in a calm and effective manner and used the experience and knowledge of another company crew to reinforce their assessment of the situation. The advice given was sound and the crew acted upon it, providing an example to less experienced aircrew who may feel that asking for advice in the midst of an incident might imply some shortcoming on their part.

The Sumburgh Radar controller reacted promptly to the emergency and controlled the incident in a confident and competent manner, vectoring the S61 helicopter to provide assistance to the crew of 'MG'.

Engineering investigation

i) General description

The AS332L stabiliser consists of an inverted aerofoil with a fixed leading edge slat. Its function is to provide downforce during the cruise, the magnitude of which is approximately 240 decanewtons (DN) at 140 kt. The principal structural element is an 80 mm diameter, cadmium plated, tubular steel spar. This emerges from the inboard root of the stabilser and passes through bushings mounted on the left and right sides of the pylon. The end of the spar is attached, via bolts, to the bushing on the right hand side of the pylon.

There is an additional structural attachment to the pylon in the form of a shackle located on the stabiliser inboard rib, just aft of the leading edge.

The spar has a glassfibre collar on its outer surface which spans the region between a flange on the inboard rib and the feed-through bushing on the left side of the pylon. The collar ensures a snug fit between the spar and the bushing. It is however prone to wear, and is the subject of a dimensional check as part of a Phase 1 inspection every 600 flight hours.

A collar which is worn beyond limits can be replaced in accordance with procedures in the Eurocopter Repair Manual. This involves removal of the old collar and inspecting the surface of the tubular spar for corrosion. If corrosion is found, it must be removed and the component inspected for cracks. The tube surface must be reprotected prior to attaching a new collar, using epoxy adhesive. The collar, as supplied, is cut longitudinally (ie spanwise) to facilitate the process of sliding it over the end of the tube and into position. In addition, the collar can be propped open by means of specially machined blocks inserted into the split, which eliminates the problem of losing adhesive from the internal surface of the collar as it is slid into position.

ii) Initial investigation

The stub of the stabiliser spar tube had remained within the pylon and it was apparent that the failure had occurred within the glassfibre collar at a spanwise station level with the inboard rib (see the accompanying photograph). The leading edge shackle had failed, in overload, in a forwards direction. In addition, there were superficial dents and paint chips to the pylon skin. It was concluded that the spar tube had failed in a downwards direction and had then flailed briefly about the shackle before becoming detached from the helicopter.

The spar stub was removed and subjected to a metallurgical examination (see later). Before the collar was removed, it was subjected to a dimensional check which revealed that it was worn slightly beyond the Maintenance Manual limits and thus would have required replacement at the next inspection. The stabiliser, together with the outer portion of the spar, was not recovered.

NB: The failure appeared similar in some respects to the only other known failure of this component, which occurred in June 1987 to Super Puma G-TIGC, and which belonged to the same operator as G-BWMG. That incident was reported in AAIB Bulletin 7/88.

iii) Horizontal stabiliser spar history

The spars, which are common to AS330 Puma aircraft, can have one of six suffixes to the basic part number. These denote minor installational differences and include changes to the surface treatment of the tube ends, and glassfibre collar widths. The basic tube is the same in all cases in terms of material specification and cadmium plating. As the components are non-lifed items, they do not have serial numbers unless one is assigned by the operator. This causes difficulty in attempting to establish an accurate history of the component. The subject spar, the date of manufacture of which was not known, had been given a number by the host aircraft's previous (Danish) operator when a new glassfibre collar was fitted in September 1992, after an estimated time in service of 7,867 hours. In May 1993 the component was installed on G-BWMG, which at that time was also in service with the Danish operator. The aircraft arrived on the UK register in November 1995. The current operator had not conducted a collar replacement on the spar, which had achieved an estimated 12,454 hours at the time of the failure.

iv) Metallurgical examination

The collar was removed from the tube without difficulty by cutting it longitudinally and peeling it off. The bond was poor and there appeared to be only small quantities of adhesive. This suggested that the replacement collar may have been assembled onto the spar without having been propped open by the blocks as described earlier.

The fracture had occurred some 11 mm from the outboard end of the collar. The internal surface of the collar was stained brown with corrosion products from the spar. The fracture had developed from a region of high cycle tension fatigue centred between approximately the 10 and 11 o'clock positions on the tube (viewed from the left side of the pylon, ie such that 9 o'clock pointed to the nose of the aircraft). This area extended over some 28 mm of circumference, with the stained nature of the fracture face suggesting that it had grown over a considerable period of time. Fatigue striations, or 'event bands', were visible adjacent to the extremities of this slow growth area. Assuming that each 'event' was a loading cycle (ie a flight), the growth rate was around 27 flights per mm. However, there was then a sudden change to extremely rapid growth simultaneously from both ends of the slow growth region. These extended forwards to the 7 o'clock and aft to the 4 o'clock positions. The remainder of the failure was tensile overload, with an area of ductile overload in the 6 o'clock position, such that a 'tongue' of material had remained, pointing downwards.

The reason for the transition to rapid crack growth was not evident, but was consistent with a sudden and substantial increase in the magnitude of the cyclic loading during the last flight.

It was apparent that very little cadmium plating and primer had remained on the surface of the tube underneath the collar. Corrosion had occurred over a discontinuous band at, and adjacent to, the fracture and was transgranular, as opposed to intergranular. Although micropitting was evident, there were no corrosion pits of significance in terms of stress concentration.

Hardness tests were carried out on the surface of the tube, after removing the cadmium plating. The results indicated that the material had a tensile strength of around 675 N/mm2.

v) Comparison with the previous failure

The spar tube from the 1987 incident had fractured in the same general area, with a fatigue crack originating from a 0.2 mm deep corrosion pit. Severe intergranular corrosion of the tube had occurred as a result of failure to reprotect the surface during collar renewal. In this case, the origin was at the 2 o'clock position, with the region of slow growth fatigue extending over 99 mm, or approximately 40% of the circumference. At each end of this region were a number of pronounced fatigue growth bands followed by a transition to fast fracture. Complete failure had not occurred however, and the helicopter had landed with the stabiliser hanging down at 90° to the horizontal.

A hardness test on the tube showed that the material had an ultimate tensile strength (UTS) of around 1025 N/mm2, ie considerably higher than the tube from G-BWMG. It was subsequently found that the surface of the latter component had been decarburised as a result of incorrect heat treatment at manufacture. The tube from the previous incident had been ground (on its outer surface) subsequent to heat treatment, thus removing most of any surface decarburisation present. It should be noted that the decarburised, and therefore softer, material at the surface would have had a correspondingly lower fatigue resistance. Any fatigue crack developing in this soft surface layer would propagate down into the harder substrate material.

It was concluded that although corrosion was present in both cases, it was of less significance in the recent failure. However, the decarburised surface in the latter would have lowered the fatigue resistance, and would have been vulnerable to crack initiation from relatively minor corrosion effects, such as micropitting.

In order to gain additional data, the AAIB obtained two scrap stabiliser spars from the operator, together with an 'airworthy' component that was in the workshops for refurbishment. It was found that the surfaces of all three spars were decarburised to a degree but, as with the component from G-TIGC, most of this had been removed by grinding. (It was additionally observed that the grinding process on the airworthy spar had left a number of deep scores on the surface capable of severely reducing the fatigue resistance of the component.)

The results of the tests on all the spars are summarised in the following table, and it can be seen that the strength of the component from G-BWMG was significantly below the others:

Component	**Lowest µ hardness just below skin Hv [0.025]**	**Mean core hardness Hv[10]**	**Mean core µ hardness Hv[0.025]**	**Mean surface hardness Hv[10]**	**Appx UTS from mean surface hardness (N/mm2)**	**Ground finish?**
Spar from G-BWMG	Not measured	Not measured	Not measured	219	675	NO
1987 Failure	279	345	357	332	1025	YES
Scrap spar # 1	321	380	412	379	1170	YES
Scrap spar # 2	327	373	383	323	995	YES
Airworthy spar	Not measured	Not measured	Not measured	Not measured	1160	YES

It should be noted that the spar tube surface finish, ie ground or otherwise, would be decided by the tube supplier, and is apparently not normally specified on the production drawing. It is probable that a grinding process would be used to achieve final dimensional accuracy of the tube.

vi) IHUMS investigation

The aircraft was equipped with an Integrated Health and Usage Monitoring System (IHUMS). This consists of a series of accelerometers mounted at various locations on the aircraft structure, including the main and tail rotor gearboxes. The system monitors vibration levels at various frequencies, with the data being stored in an on-board computer which is down-loaded on a daily basis for analysis by engineering personnel. The data is then automatically monitored for threshold level exceedences, although trend monitoring is carried out manually. This process provides an opportunity for any developing problems in the power train, such as imbalances in rotor blades, gearboxes or driveshafts, to be identified at an early stage.

In the air, data acquisition is generally automatic with, for example, data 'snapshots' being taken during climb, descent and at hourly intervals during the cruise. Although the system is optimised for monitoring the dynamic components, any changes in vibration signatures can also signify a change in airframe structural integrity.

Following this incident, the tail rotor gearbox input shaft vibration trace was examined and this showed a three-fold increase in magnitude during the last three hours prior to the separation of the stabiliser. This was thought to be a function of the decreasing stiffness of the stabiliser, as the crack in the spar progressed, which excited the accelerometer mounted on the tail rotor gearbox. However, there was also the possibility of a problem elsewhere feeding vibratory loads into the stabiliser, which might have explained the reason for the rapid crack growth. The IHUMS data was obtained for several flights following the aircraft's return to service with the replacement stabiliser. (Note: the rotor head was also changed as a precaution, following Eurocopter's concerns at the extreme pitch-down reported by the crew). It was found that the vibration had returned to the levels recorded before the final three hours of the incident flight, thus suggesting that the high values were indeed caused by the progressively failing stabiliser. Nevertheless, the opportunity was taken to pass the raw data to a specialist organisation which subjected it to a series of complex algorithms with the object of highlighting trends that may otherwise not have been evident. However no such trends were detected.

It was also noted that the 1R (ie once per main rotor revolution) signature from a vertically orientated transducer mounted on the pylon close to the tail rotor gearbox showed a significant increase in amplitude over the two days preceding the incident. This was ascribed to an out-of-track main rotor blade following a rotor head change on 26 January, which was carried out for operational reasons. However, such imbalances occur relatively frequently and it did not therefore seem likely that this could have generated a substantial increase in the cyclic loading on the stabiliser spar.

vii) Post incident action by the operator

After this incident, the operator decided to apply additional collar sealing, together with polyeurethane paint, on all new spars received from the manufacturer. In service components will be rotated back to the workshop, regardless of condition, to be overhauled with new collars. Traceability will be guaranteed by allocation of an operator-specific part number and serial numbers. It is also intended to impose a maximum period of three years between overhaul, although this will be reviewed in the light of experience.

Discussion and Safety Recommendation

The metallurgical investigation revealed that the spar had failed due to a fatigue crack that had initiated due to a combination of corrosion micropitting and reduced material strength. The corrosion had occurred as a result of improper procedures during glassfibre collar replacement by the aircraft's previous operator. The spar material from G-BWMG was found to be significantly weaker than others that were examined during the course of the investigation. This was mostly due to surface decarburisation, which on the other spars had largely been removed by a grinding process. The presence of a decarburised surface layer would have rendered the spar more vulnerable to fatigue crack initiation.

The sudden change to rapid crack growth that preceded the failure of the spar, and which was not apparent on the 1987 spar failure, was not explained. There appeared to be little scope for increasing the cyclical loads during the normal flight regime, and the IHUMS data analysis excluded the possibility of a developing imbalance in the rotor or transmission system exploiting the fatigue crack. It is possible however that the normal vibratory loads in the spar may have been amplified due to the accumulation of ice on the stabiliser; there was a remark on the CVR concerning the onset of airframe icing approximately 30 minutes before the spar failure.

The lack of adequate reprotection of the spar surface following collar replacement was the primary cause of the 1987 spar failure and may have been a factor in the recent failure. G-BWMG's current operator has (since 1987) invested in the skills and facilities necessary to overhaul stabiliser spars to the required standard. This may not be the case for smaller operators, with the result that any airworthiness action taken to address the problem should avoid unnecessary disturbance of the collar. The fact that the latest incident concerned a material strength issue, the fleetwide extent of which was not apparent, suggested that it may be more appropriate to identify the weaker, decarburised stabiliser spars. The following Safety Recommendation has therefore been made:

Safety Recommendation No 98-46

In view of the probability that a number of horizontal stabilisers, as manufactured and fitted to AS330/332 helicopters, may have been weakened by the presence of a decarburised surface layer on their steel spars, it is recommended that:

> i) Eurocopter should determine the minimum surface hardness value consistent with the spar material being of adequate strength.
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> ii) The Direcion General de L'Aviation Civile (DGAC) should require that AS330/332 horizontal stabiliser spars be subjected to a once-only surface hardness check at the next scheduled inspection, in order to establish that the spar material is of adequate strength.

Eurocopter response to Safety Recommendation No 98-46

The manufacturer responded to the Draft copy of this Bulletin and Safety Recommendation No 98-46, which was circulated on 10 June 1998, with the following information on 2 July 1998:

> " Eurocopter has presented the same recommendation as AAIB to the French Civil Aviation Authorities (DGAC): all spar tubes installed on SA 330/AS 332 aircraft or held as spares will be checked. A minimum hardness value will be determined for this check."